ALASKA FISHERIES SCIENCE CENTER

EFFECTS OF FISHING GEAR ON SEAFLOOR HABITAT PROGRESS REPORT FOR FY 2004

edited by
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In 1996, the Alaska Fisheries Science Center (AFSC) initiated a number of seafloor habitat studies directed at investigating the effects of fishing on seafloor habitat. Each year a progress report for each of the projects is completed. A list of the 36 publications that have resulted from these projects is also included. Scientists primarily from the Auke Bay Laboratory (ABL) and the Resource Assessment and Conservation Engineering (RACE) Divisions of the AFSC have been conducting this work. A web page http://www.afsc.noaa.gov/abl/MarFish/geareffects.htm has been developed that highlights these research efforts. Included in this web page are a research plan, previous progress reports, and a searchable bibliography on the effects of mobile fishing gear on benthic habitats.

Determining the value of habitat to juvenile rockfish in the Aleutian Islands. Principal Investigators - Chris Rooper and Mark Zimmermann (AFSC – RACE), and Jennifer Boldt (University of Washington)

Linking the specific benefits of habitats to fish is important to determining Essential Fish Habitat for species. The objective of this study is to assess the value of Aleutian Islands habitat to juvenile (< 250 mm fork length) Pacific ocean perch (POP) by examining abundance, condition and growth in five study areas. The initial phase of habitat mapping was completed during a research cruise beginning and ending in Dutch Harbor, Alaska from May 28 to June 9, 2004. Video transects and sediment samples were completed in a cruise from August 13-24, 2004. Each of five study areas surrounding the Islands of Four Mountains was mapped using a towed side scan sonar (Klein 3000) and a multibeam system (Simrad SM2000), to collect bathymetry and backscatter data. Much of the data processing was completed aboard the F/V *Ocean Explorer* and side scan sonar mosaics were produced (Fig. 1). In total, 25 km^2 were mapped using side scan sonar, and multibeam data was collected over almost twice that area. Video and sediment samples were collected to groundtruth the acoustic data. Preliminary results indicate habitats at each area varied widely, from bare sand fields to rocky ledges, ridges and pinnacles. Sponge and coral were the dominant epibenthic invertebrates observed in the video and trawl collections. Juvenile POP were collected from 4 of the 5 study areas for laboratory analyses. Sponge and coral were observed at most sites where juvenile POP were collected. During the fall and winter of 2004-05 sediment samples, zooplankton, and fish collections will be analyzed in the laboratory, and data analyses will begin later. The approach presented here will provide information to determine the value of habitats to their inhabitants, as well as insight into the processes controlling fish-habitat relationships. This project was supported by a grant from the North Pacific Research Board.

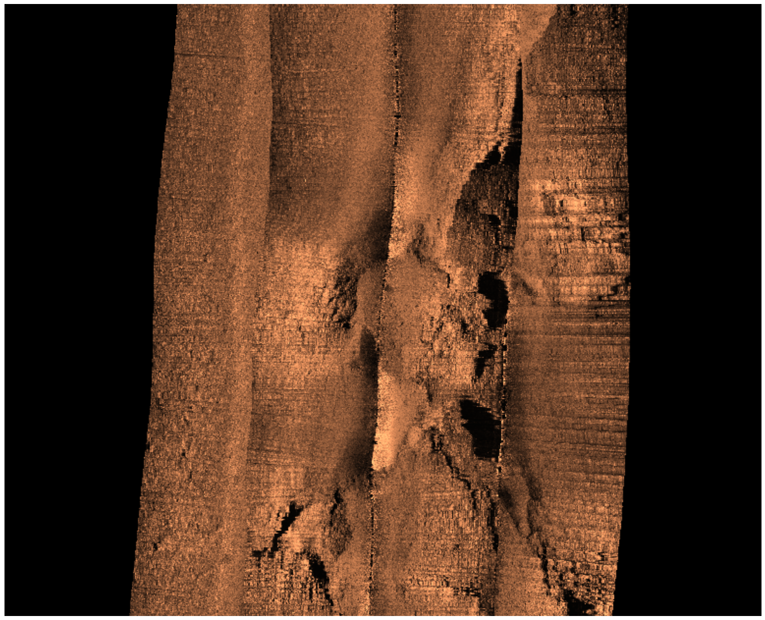

Figure 1. Side scan sonar mosaic from the Islands of Four Mountains west study location, showing interesting geological features on the seafloor.

Distribution of deep-water corals and associated communities in the Aleutian Islands. Principal Investigators - Robert Stone (AFSC - ABL), Jon Heifetz (AFSC - ABL), Doug Woodby (Alaska Department of Fish and Game), and Jennifer Reynolds (University of Alaska, Fairbanks)

During July 24 – August 8, 2004 the ROV *Jason II* (Woods Hole Oceanographic Institute) and support vessel RV *Roger Revelle* were used to study deep-sea coral and sponge habitat in the central Aleutian Islands. The dives made with the *Jason II* were at ten sites from 131 m to 2948 m in depth. Video footage of the seafloor was collected along strip transects from 2.4 to 13.2 km in length. Corals and sponges were widely distributed at the study sites with an apparent change in density, diversity, and species composition at a depth of approximately 1400 m. Samples were collected at stations along transects and included 260 corals, 45 sponges, 165 miscellaneous invertebrates, and 82 rocks. Preliminary results indicate that representatives from all seven coral families known to occur in the North Pacific were collected and that several of the collected sponges represent species new to science.

NOAA's Undersea Research Program funded the cruise and this was the final component of a comprehensive study initiated in 2003 and funded by the AFSC and the North Pacific Research Board. Coupled with detailed multibeam mapping and previous in-situ observations in shallow water (< 365 m) these findings will be used to construct a model to predict where coral habitat is located in the Aleutian Islands. The model will provide fisheries managers with a powerful tool to conserve coral habitat. Results from this cruise will provide information on the distribution of corals and sponges in the Aleutian Islands that will aid in fisheries management decisions. Our findings will greatly add to the understanding of the role of corals and sponges in seafloor ecology and their susceptibility to disturbance. An overview of the coral research can be seen at http://www.alaskascienceoutreach.com/

Bogoslof Island mapping and colonization. Principal Investigators - Mark Zimmermann (AFSC - RACE), Jennifer Reynolds (University of Alaska Fairbanks), and Chris Rooper (AFSC - RACE)

We are studying the colonization process of benthic invertebrates at hard-bottom sites about 10-200 years old on Bogoslof Volcano to provide estimates of habitat recovery rates from benthic fishing activities.

Bogoslof provides a natural laboratory for our study because lava and tephra (fragments of volcanic rock and lava) from historical eruptions (since 1796) have resurfaced different areas of the shallow seafloor around the island. The results will provide information needed for fisheries management by defining an upper bound on the time needed for recovery. Currently there are no reliable estimates of habitat recovery time from field work, and recovery rates on hard-bottom areas have been estimated as 1-9% per year whereas gorgonian coral recovery rates were estimated as 0.5-2% per year (or 50-200 years) for use in the Fujioka habitat impacts model.

The project involves three separate stages of research: mapping the seafloor, matching seafloor areas to specific eruptions (dates), and conducting an ROV census of benthic invertebrates within seafloor areas of known ages. The first phase of the project was completed in July 2004 when a contract survey company successfully mapped the seafloor surrounding Bogoslof with a 100 kHz Reson SeaBat 8111 multibeam at depths from 20 to 750 m (Fig. 2). After the final multibeam maps are delivered, the second phase will be completed this winter, and we will develop a census plan for studying the invertebrates. In summer 2005 we plan to conduct ROV transects within selected seafloor patches. We anticipate that there may be three possible levels of resolution for the video census: 1) presence/absence of species or taxa groups, 2) density or percent horizontal coverage, and 3) age estimates of individuals.

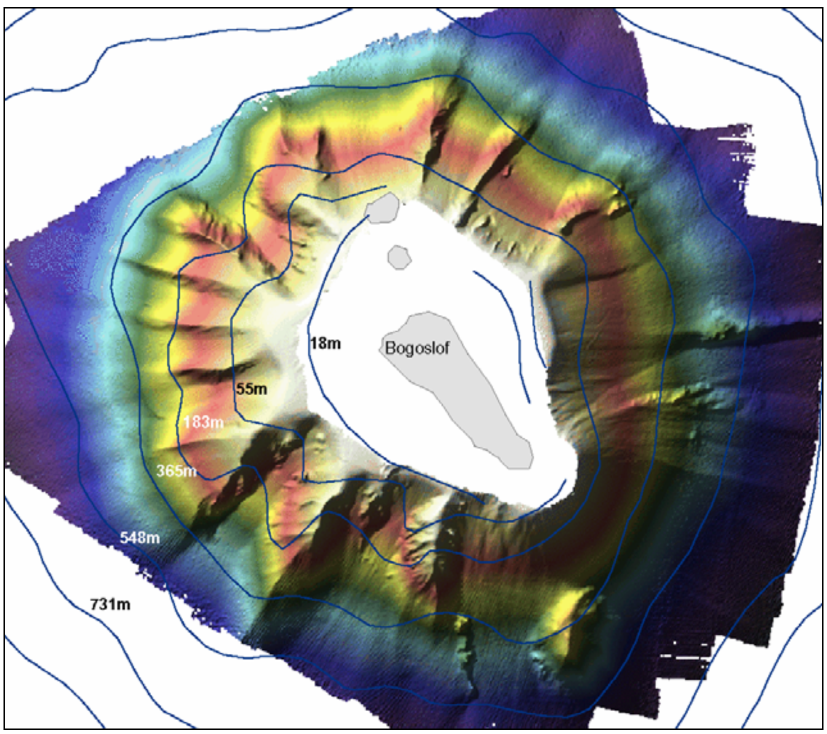

Figure 2. Preliminary multibeam map of the seafloor surrounding Bogoslof Island. Relief is artificially shaded from the northwest.

A model for evaluating fishery impacts on habitat Principal investigator - Jeffrey Fujioka (AFSC - ABL)

A mathematical model to evaluate the effects of fishing on benthic habitat was developed within the context of the Programatic and Essential Fish Habitat (EFH) supplemental environmental impact statements (EIS). The initial formulation of the model was comprised of equations that incorporate the basic factors determining impacts of fishing on habitat. Given values, either estimated or assumed, of 1) fishing intensity, 2) sensitivity of habitat to fishing effort, and 3) habitat recovery rate, the model predicts a value of equilibrium (i.e., long term) habitat level, as a proportion of the unfished level.

In 2004 new equations were formulated to expand on application of the model. In addition, model properties and new examples were developed which provide guidance in evaluating or designing mitigation strategies. The equations in the initial development of the model dealt with constant fishing effort situations and the EIS habitat impact analyses compared hypothetical equilibrium levels. During review of the EFH EIS concerns were raised about the current status of habitat impact. One new equation provides a simple way to determine the time it takes to approach equilibrium habitat reduction. Another equation was derived to extend model application to non-constant fishing effort so that if actual fishing effort history exists, habitat reduction over time can be modeled.

Distribution of juvenile Pacific ocean perch (*Sebastes alutus*) in the Aleutian Islands. Principal Investigators - Chris Rooper (AFSC - RACE) and Jennifer Boldt (University of Washington)

The objective of this research was to identify juvenile (< 250 mm fork length) Pacific ocean perch (POP) habitat, using data from trawl surveys conducted by NMFS. Analyses were carried out to evaluate the POP CPUE relationship to depth, temperature, and sponge and coral CPUE. A principal component analysis indicated that sponge and coral CPUE were tightly linked, and depth and temperature were negatively correlated. The survey data indicate that juvenile POP were present at depths from 76 to 225 m (Fig. 3). Juvenile POP CPUE increased with depth from 76 to 140 m, and decreased with increasing temperature from 3 to 5.5 ºC. Juvenile POP CPUE also increased with increasing sponge and coral catch rates (Fig. 4). A statistical model predicting juvenile CPUE at stations where POP were caught explained 34% of the CPUE variability using bottom temperature, depth, and combined sponge and coral CPUE. Juvenile POP were most abundant at sites in the western Aleutians (beyond 170º W longitude), on large underwater banks (Stalemate and Petrel banks), and in passes between islands where currents are strong and production may be higher than surrounding areas. These results suggest sponge and coral have an important role in the early life history of juvenile POP.

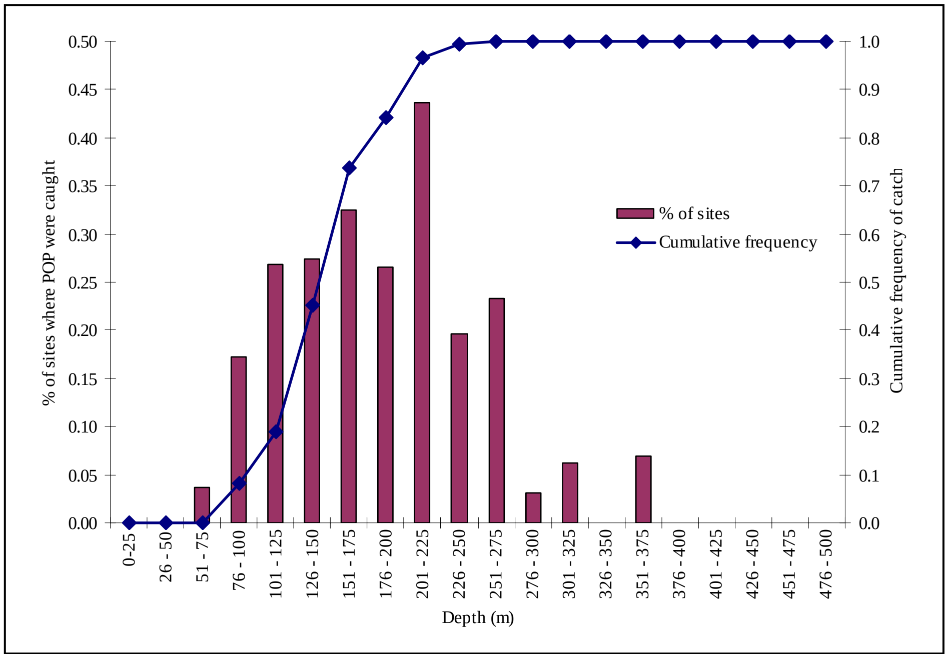

Figure 3. Cumulative frequency distribution of juvenile POP catch and proportion of trawl survey sites with rockfish present. Data are presented in 25-m depth bins.

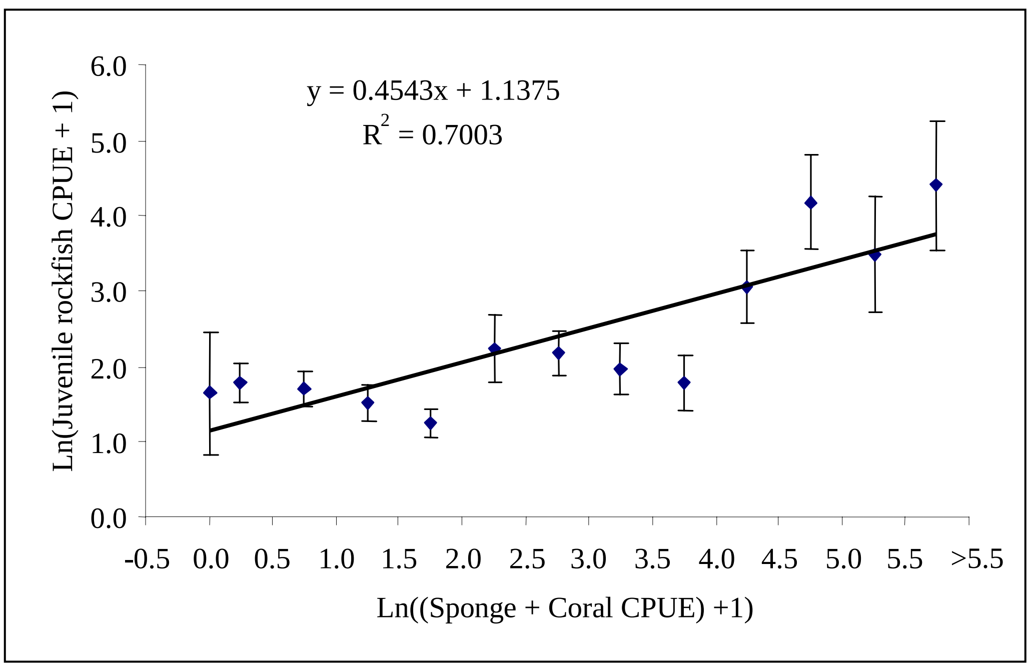

Figure 4. Relationship between sponge and coral CPUE (kg/ha) and juvenile POP CPUE (no./ha) at sites where juvenile POP were caught. Data are divided into 0.5 CPUE bins and each data point is plotted in the center of its bin.

Effects of experimental bottom trawling on soft-sediment sea whip habitat in the Gulf of Alaska. Principal Investigator - Robert Stone (AFSC - ABL)

In June 2001 a study was initiated to investigate the immediate effects of intensive bottom trawling on soft-bottom habitat and in particular an area colonized by sea whips. Sea whip biological characteristics and their resistance to two levels of trawling were studied. Sea whips are highly visible and changes in their abundance can be readily quantified. Within the study site, at least two species of sea whips (*Halipterus willemoesi* and *Protoptilum* sp.) are present with densities up to 10 individuals per m^2. Sea whip beds provide vertical relief to this otherwise homogeneous, low relief habitat. This habitat may be particularly vulnerable since sea whips can be removed, dislodged, or broken by bottom fishing gear. Furthermore, since sea whips are believed to be long-lived, recolonization rates may be very slow.

The study plan consisted of three phases. In *Phase 1*, baseline data was collected. The *Delta* submersible was used to collect *in situ* videographic documentation of the seafloor along 20 predetermined transects within the study area. Additionally, a bottom sampler was deployed from the submersible tender vessel to collect sediment samples (n=42) from the seafloor. During *Phase 2*, a commercial trawler outfitted with a Bering Sea combination 107/138 net, mud gear, and two NETS High Lift trawl doors made a single trawl pass in one corridor of the study area and repetitively trawled (six trawl passes) a second corridor. A third corridor was the control and was not trawled. *Phase 3* repeated the videographic and sediment sampling (n= 42) following the trawling phase. A scientist on board the *Delta* observed the seafloor and verbally identified biota and evidence of trawling including damaged or dislodged biota and marks on the seafloor from the various components of the bottom trawl (e.g., trawl door furrows, and ground gear striations) in synchrony with the external cameras. Analyses of sediment, chemical, and infauna abundance and diversity were completed in 2002. Video analysis of epifauna data was completed in Spring 2003 and data analyses are underway.

Growth and recruitment of an Alaskan shallow-water gorgonian coral. Principal Investigator - Robert Stone (AFSC - ABL)

Little is known about the growth rates and lifespan of cold-water gorgonian coral. Some evidence exists that growth rates for these habitat-forming corals are low and that they are long-lived. Consequently, recovery rates from disturbance are likely slow. A study was initiated in 1999 to examine the growth and recruitment of *Calcigorgia spiculifera*, the most common and abundant species of shallow-water gorgonian in Alaskan waters. During June and July 2004 two sites established in July 1999 were revisited and 36 of 38 tagged colonies were relocated and video images recorded. These images will be digitized and growth determined from baseline images collected during the five previous years. A third study site was established in Kelp Bay, Baranof Island in 2000 where 30 colonies were tagged and images recorded. This site was unique in that it contained more than 1000 colonies, many of which were young (i.e., non-arborescent). At this site 18 of 30 colonies were relocated in July 2004 and video images were recorded. Additionally, branch samples were collected from untagged colonies at all three locations in 2002 and 2003 and will be examined microscopically to determine the gonadal morphology, gametogenesis, and reproductive schedule for this species. This research on reproductive biology should provide insights into the capability of cold-water gorgonians to recolonize areas set aside as mitigative measures, such as Marine Protected Areas.

Age validation and growth of three species of Pennatulaceans. Principal Investigator - Robert Stone (AFSC - ABL)

Pennatulaceans (sea whips and sea pens) are locally abundant in Alaskan waters, susceptible to disturbance by bottom fishing activities, and are an important structural component to benthic ecosystems. Furthermore, research on one species (*Halipterus willemoesi*), indicates that they are long-lived and have low growth rates. This research was based on ring couplet (growth rings) counts but the periodicity of the couplets was not verified. To determine if the couplets are indeed annuli, 14 *Halipterus willemoesi* colonies were immersed in calcein solution and tethered to the seafloor where they were collected at 25 m depth. Preliminary results indicated that the calcein produced clear detectible marks on the axial rods. The 14 tethered specimens were retrieved between March and September 2004. Examination of these specimens is currently underway and may provide verification of the periodicity of ring couplets.

Axial rods from approximately 20 specimens each of the sea whips *Halipterus willemoesi* and *Protoptilum* sp. and the sea pen, *Ptilosarcus gurneyi*, are being examined for ring couplet counts. Examination of a wide size range for each species will provide estimates of growth rate, asymptotic size, and life span. One species (*Halipterus willemoesi*) will be collected from two populations subjected to different temperature regimes (Southeast Alaska and Bering Sea) and will allow us to examine the effects of temperature on growth rates. These data will allow us to estimate the growth rates of pennatulaceans throughout their geographical range and depth distribution.

Effects of bottom trawling on soft-sediment epibenthic communities in the Gulf of Alaska. Principal Investigator - Robert Stone (AFSC - ABL)

In April 1987 the North Pacific Fishery Management Council closed two areas around Kodiak Island, Alaska to bottom trawling and scallop dredging (Type 1 Areas). These areas were designated as important rearing habitat and migratory corridors for juvenile and molting crabs. The closures are intended to assist rebuilding severely depressed Tanner and red king crab stocks. In addition to crab resources, the closed areas and areas immediately adjacent to them, have rich stocks of groundfish including flathead sole, butter sole, Pacific halibut, arrowtooth flounder, Pacific cod, walleye pollock, and several species of rockfish.

These closures provide a rare opportunity to study the effects of an active bottom trawl fishery on soft-bottom, low-relief marine habitat because bottom trawling occurs immediately adjacent to the closed areas. In 1998 and 1999 studies were initiated to determine the effects of bottom trawling on these soft-bottom habitats. The goal of these studies was to determine if bottom trawling in some of the more heavily trawled areas of the Gulf of Alaska, has chronically altered soft-bottom marine communities. Direct comparisons were possible between areas that were consistently trawled each year and areas where bottom trawling had been prohibited for 11 to 12 years. The proximity of the closed and open areas allowed for comparison of fine-scale infauna and epifauna diversity and abundance and microhabitat and community structure. Continuous video footage of the sea floor was collected with an occupied submersible at two sites that were bisected by the boundary demarcating open and closed areas.

The positions of 155,939 megafauna were determined along 89 km of seafloor. At both sites we detected general and site-specific differences in epifaunal abundance and species diversity between open and closed areas that indicate the communities in the open areas had been subjected to increased disturbance. Species richness was lower in open areas. Species dominance was greater in one open area, while the other site had significantly fewer epifauna in open areas. Both sites had decreased abundance of low-mobility taxa and prey taxa in the open areas. Site-specific responses were likely due to site differences in fishing intensity, sediment composition, and near bottom current patterns. Prey taxa were highly associated with biogenic and biotic structures; biogenic structures were significantly less abundant in open areas.   In addition a relationship between epifaunal biomass and sea whip abundance was apparent. This relationship indicates that sea whip habitat may have increased productivity. Recent studies in the Bering Sea have shown a similar functional relationship for sea whip habitat. Evidence exists that bottom trawling has produced changes to the seafloor and associated fauna, affecting the availability of prey for economically important groundfish. These changes should serve as a “red flag” to managers since prey taxa are a critical component of essential fish habitat. Results from the epifauna component of this study were presented at Effects of Fishing Activities on Benthic Habitats symposium held in Tampa during November 2002 and will be published in the American Fisheries Society Symposium 41.

Ecological value of physical habitat structure for juvenile flatfishes Principal Investigator – Allan W. Stoner (AFSC - RACE)

Our previous field and laboratory studies have shown that some juvenile flatfishes have strong preferences for habitats with physical structure created by large epibenthic invertebrates, biogenic structures in the sediment, and sand waves. New experiments in large laboratory pools revealed that predation vulnerability of with age-0 rock sole and Pacific halibut decreases substantially in the presence of habitat complexity presented by sponges. Predator-prey encounter rates decreased with habitat structure as predator swim speed and search behavior was impeded. Physical structure in the environment also impeded pursuit of prey. Young halibut were more likely to flee from predators than rock sole, but once flight was initiated halibut were more likely to escape than rock sole because of greater speed and agility. Subsequent experiments have shown that mortality decreases with amount of structural complexity, but the function is not linear. These experiments support an accumulating body of evidence that emergent structure in otherwise low-relief benthic habitats may play a critical role in the survival and recruitment of juvenile flatfishes.

During 2003 and 2004, field experiments were conducted near Kodiak to increase the structural complexity of large bare sand plots within flatfish nurseries. Bivalve shells were added (5 shells/m^2) to replicated plots. The modified plots and reference plots were then monitored with a towed camera sled at several intervals over the following month to characterize changes in the fish fauna occupying those plots. Unexpectedly, numbers of age-0 flatfishes decreased inside the structurally enhanced plots, but older flatfishes increased in abundance. Subsequent laboratory experiments showed that both large and small flatfishes are attracted to structurally complex habitats, but disturbance by the larger flatfishes resulted in the smallest fishes moving away. This illustrates the complexity of mechanisms behind fish/habitat associations.

Camera sled surveys for juvenile flatfishes were continued in three key nursery grounds near Kodiak during 2004, with the purpose of quantifying flatfish/habitat associations. Surveys were expanded to include a seasonal component during the early summer to fall recruitment season. Surveys have now been conducted for three years, yielding ~150 hours of video tape. Analysis of the video is currently underway. Statistical and spatially-explicit analyses of the distribution patterns will begin during FY-05. The densities of age-0 flatfishes recorded with our small camera sled are equivalent to the values provided in diver surveys and with small beam trawls. The camera gear, integrated with navigational data, provides a permanent record of the habitat, can be used for large spatial coverage, and has been a very effective way to explore fish/habitat associations.

Mapping marine benthic habitat in the Gulf of Alaska: geological habitat, fish assemblages, and fishing intensity. Principal Investigators - Jon Heifetz (AFSC – ABL), Kalei Shotwell (AFSC – ABL), Dean Courtney (AFSC – ABL), and Gary Greene (Moss Landing Marine Labs)

Since 2001 we have mapped about 4,000 km^2 of seafloor in the Gulf of Alaska using a high-resolution multibeam echosounder that includes coregistered backscatter data. The mapping has mainly focused on areas in the vicinity of major groundfish fisheries such as Portlock Bank, Albatross Bank, Pamplona Spur, and Yakutat slope. This past year we focused our analyses on the 790 km^2 mapped area on Portlock Bank northeast of Kodiak. We evaluated the utility of integrating various sources of biological data with high resolution bathymetry and backscatter for describing benthic habitat, fish/habitat associations, and habitat specific fishing intensity. The biological information evaluated included data acquired from programs external to our study such as fishery observer data and trawl survey data and new data from the multibeam mapping and submersible dive transects. Habitat classification derived from mapping data indicated the presence of twenty-two different benthic habitats. Although biological data were limited on the mapped site for identifying fish/habitat associations and habitat specific fishing intensity, we were able to determine general and habitat specific fish distributions over the surveyed area through occurrence measurements and density calculations. We also created a density surface of the commercial fishing trawls in the mapped area that enabled examination of basic patterns in fishing intensity by habitat type. We recommend a directed survey that collects biological samples in each of the established benthic habitats for more quantitative measurements of fish-habitat preference. Other properties within the area, such as oceanography and predator/prey fields, may also influence fish distributions and should be considered during benthic habitat classification.

Red king crab and bottom trawl interactions in Bristol Bay. Principal Investigators - C. Braxton Dew and Robert A. McConnaughey (AFSC - RACE)

The 1976 U.S. Magnuson-Stevens Fishery Conservation and Management Act effectively eliminated the no-trawl zone known as the Bristol Bay Pot Sanctuary, located in the southeastern Bering Sea, Alaska. Implemented by the Japanese in 1959, the boundaries of the Pot Sanctuary closely matched the well-defined distribution of the red king crab (*Paralithodes camtschaticus*) population's mature-female brood stock, thus affording a measure of protection to the reproductive potential of the stock. In 1980, the point at which the commercial harvest of Bristol Bay legal-male red king crab reached an all-time high after a decade-long increase, domestic bottom trawling in the brood-stock sanctuary began in earnest with the advent of a U.S.-Soviet, joint-venture, yellowfin sole fishery. In the first year of trawling in the Pot Sanctuary, the Bering Sea/Aleutian Islands (BSAI) red king crab bycatch increased by 371% over the 1977-79 average; in 1981 the BSAI bycatch increased another 235% over that in 1980, most of which were mature females. As the number of unmonitored domestic trawls in the brood-stock area increased rapidly after 1979 and anecdotal reports of "red bags" (trawl cod-ends plugged with red king crab) began to circulate, the proportion of males in the mature population (0.25 in 1981 and 0.16 in 1982) jumped to 0.54 in 1985 and 0.65 in 1986. It is unlikely that normal demographics caused this sudden reversal in sex ratio. Our hypothesis is that sequential, sex-specific sources of fishing mortality were at work. Initially there were ten years (1970-1980) of increasing, male-only exploitation in the directed pot fishery, followed by a drastic reduction in the male harvest after 1980 (to zero in 1983). Then, beginning around 1980, there was an increase in bottom trawling among the highly aggregated, sexually mature female brood stock concentrated near the western end of the Alaska Peninsula, an area documented by previous investigators to be the most productive spawning, incubation, and hatching ground for Bristol Bay red king crab. There has been considerable discussion about possible natural causes (e. g., meteorological regime shifts, increased groundfish predation, epizootic diseases) of the abrupt collapse of the Bristol Bay red king crab population in the early 1980s. Our research focused on the association between record harvests of male crab in the directed fishery, the onset of large-scale commercial trawling within the population's primary reproductive refuge, and the population's collapse.

Short-term trawling effects and recovery monitoring in the eastern Bering Sea (2001-present). Principal Investigator - Robert A. McConnaughey (AFSC - RACE Division)

Whereas our earlier work focused on chronic effects of trawling this ongoing multi-year study is a process-oriented investigation of short-term effects and recovery using a BACI experimental design. The study area is located within the Crab and Halibut Protection Zone 1 closed area, approximately 25-50 mi south and west of the chronic effects site. During a 35-day cruise in 2001, 6 pairs of predesignated 10-mi long research corridors were sampled before and after a trawling disturbance with commercial gear (NETS 91/140 Aleutian cod combination). Biological sampling consisted of 15 min research trawls for epifauna (n=72 total) and 0.1 m^2 van Veen grab samples for infauna (n=144 total at 2 per epifauna site). At each infauna-sampling site, a second grab sample (n=144 total) was collected for characterizing carbon and nitrogen levels in surficial sediments, as well as grain size properties. The experimental and control corridors were also surveyed before and after trawling using a Klein 5410 side scan sonar system, to evaluate possible changes in sediment characteristics and bedforms. Taken together, the 2001 data quantify short-term changes in the experimental corridors due to trawling.

To investigate the recovery process, these same corridors were resampled in 2002 during a 21-day cruise aboard the same 155' trawler *F/V Ocean Explorer*. Sampling effort was equally divided between experimental and control corridors and was consistent with the level of effort in 2001. There was no commercial trawling event in 2002. A total of 36 epifauna trawls, 72 infauna grabs, 72 sediment grabs, and one side scan survey per corridor were performed. Combined, these data quantify recovery in the experimental corridors after one year using corrections for temporal variability measured in the control corridors.

The experimental design for this study will accommodate one additional series of epifauna sampling and multiple years of grab sampling after 2002, however the final recovery monitoring event has not yet been scheduled. At present, processing of all 2001 and 2002 samples is complete and analysis is pending. Preliminary observations indicate a very diverse epifaunal community (approximately 90 distinct taxa) on very-fine olive-gray sand at 60 m depth. The seafloor appears to be brushed smooth in the 2001 side scan imagery, probably due to sizable storm waves and strong tidal currents that regularly disturb the area. Occasional video deployments on the trawls indicated somewhat greater complexity. Derelict crab pots are scattered throughout the study area and there is evidence of extensive feeding by walrus.

A systematic framework for assessing mobile fishing gear effects. Principal Investigators Robert A. McConnaughey and Cynthia Yeung (AFSC – RACE Division)

To some degree, our understanding of fishing gear impacts is constrained by the experimental methods being used. In general, the process of understanding mobile gear effects has three distinct phases. It begins with the identification of changes caused by gear contact, followed by controlled studies to determine the ecological effects and, ultimately, decision making based on some form of cost-benefit analysis. Nearly all of the research to date has targeted the specific changes in benthic invertebrate populations that occur when mobile fishing gear, particularly bottom trawls, contact the seabed. This worldwide focus on benthic invertebrates reflects their limited mobility and vulnerability to bottom-tending gear, and observations that structurally complex seabeds are an important element of healthy productive benthic systems. Effects are typically measured as changes in abundance or community structure. However, despite decades of intensive research, the overall impact of mobile fishing gear on marine ecosystems and, in particular, on fish production is largely unknown. This reflects a need for substantially more research on the ecology of the affected invertebrates and their linkages to managed fish stocks, as well as more systematic studies of disturbance effects. Although certain gross generalities are possible, site-specific results are likely given variation in the composition of the benthos as well as the intensity, severity and frequency of both natural and anthropogenic disturbances. Because of the manner in which study areas are typically selected, any application of findings to other geographic areas is extremely tenuous. As such, there is a strong need to examine the issue more systematically so that research can move ahead from "case studies" of effects to the more interpretive (i.e. second) phase of investigation. To this end, we are working to identify areas with distinct invertebrate assemblages within which replicated *experiments* (not samples) could be placed and the aggregate findings applied to the entire area. The approaches being investigated are of two primary types and are detailed in sections that follow: (1) mapping surficial sediments as a physical proxy for invertebrate assemblages, given benthic organisms have demonstrated strong affinities for particular substrates and (2) analyzing spatial patterns of the benthic invertebrates themselves. Whereas the former approach has potential advantages in terms of cost and relatively rapid spatial coverage, the latter has clear advantages related to the direct nature of the measurements since, after all, invertebrates are the *de facto* measure of gear effects.

Evaluating single beam echosounders for synoptic seabed classification. Principal Investigators Robert A. McConnaughey and Stephen Syrjala (AFSC – RACE Division)

Acoustic technology is particularly suited to synoptic substrate mapping since quantitative data are collected rapidly and in a cost-effective manner. The QTC View seabed classification system (Quester Tangent Corporation, Sidney, B.C.) is capable of background data acquisition during routine survey operations. Echo returns from the seafloor were simultaneously collected at two frequencies (38 and 120 kHz) along a 9,000 nm trackline in the eastern Bering Sea (EBS) during a 1999 hydroacoustic fishery survey on the *R/V Miller Freeman*.

Acoustic diversity directly represents substrate diversity. Surface roughness, acoustic impedance contrast, and volume homogeneity are characteristic of different seabed types, and these factors influence echo returns from a vertical-incidence echo sounder. The standard QTC method uses a set of algorithms to extract features from individual echoes. These features include cumulative amplitude and ratios of samples of cumulative amplitude, amplitude quantiles, amplitude histogram, power spectrum, and wavelet packet transform. Principal components analysis (PCA) is used to reduce the full set of features to the three linear combinations that explain a large fraction of echo (seabed) variance. A three-factor cluster analysis then groups the echoes into distinct seabed types based on their acoustic diversity. Variation in continuous seabed properties is thus represented in discrete classes of seabed. The optimum classification scheme for any particular data set strikes a balance between high information content (i.e., many acoustic classes) and high confidence in the assigned class (e.g., if only one class). Clustering methods typically require significant user input to decide which class to split next and when to stop splitting. To overcome this subjectivity and develop a fully-automated objective process, a new application of the Bayesian form of the Akaike Information Criterion (BIC) was developed to guide the clustering process. Because of the computational intensity of the Bayesian method, analytical methods based on simulated annealing have been introduced to improve the program's ability to locate the global minimum (rather than a local minimum) of the BIC function. Alternatively, the three principal components may themselves be used to represent acoustic seabed diversity.

Results of this collaborative research with QTC include guidelines for acoustic mapping of seabeds and an optimal classification scheme for the EBS shelf. A total of 14 distinct classes of bottom types (clusters) were identified from the 38 kHz data. These results have now been merged with 22 years of RACE trawl survey data from the EBS shelf (1982-2003). Statistical analyses are being conducted to examine the degree to which acoustic variability corresponds to environmental features that influence the distribution and abundance of groundfish and benthic invertebrates.

Reconnaissance mapping with side scan sonar. Principal Investigator Robert A. McConnaughey (AFSC – RACE Division)

Upon completion of the 2002 bottom trawl study in the eastern Bering Sea, a reconnaissance of Bristol Bay seafloor habitats was undertaken using a high-resolution 500 kHz side scan sonar (Klein 5410). The reconnaissance effort was centered on an 800 mi^2 area of central Bristol Bay that has never been surveyed by NOAA hydrographers. The primary research objective is to identify large homeogenous regions that would be the basis for more systematic study of mobile gear effects. Secondary objectives include a study of walrus feeding ecology, a comparison of supervised and unsupervised classification methods for EFH characterization, and potential updates of nautical charts for the area.

A 150 m swath of bathymetric data and imagery were collected along survey lines totaling nearly 600 linear miles. The survey intentionally intersected six of the Bering Sea trawl study corridors currently being studied (above) in order to provide a spatial context for these results. In support of coordinated EFH characterization studies in the area, the reconnaissance survey also crossed 18 RACE Division trawl survey stations and followed 78 mi of seabed previously classified using a *QTC View* single beam acoustic system. Imagery was systematically groundtruthed using an underwater video camera and van Veen grab samples. Overall, a great diversity of complex sand-bedforms and other geological features were encountered in the survey area.

Thus far, a subset of the data has been classified using geological (supervised) and statistical (unsupervised) methods. A new software product, *QTC Sideview*, uses automated processing techniques to read the data on a line by line basis, segment the imagery, extract features based on pixel intensity and image texture, and classify the segments using multivariate statistics. Thirteen distinct acoustic classes were identified. A geologist identified seven major bottom types: (1) degraded bedforms, (2) hummocky seabed, (3) mixed sediments, (4) sand lenses, (5) smooth seabed, (6) sand ribbons, and (7) sand waves, with subdivisions loosely based on scale and shape of features, acoustic reflectivity, and presence or absence of walrus feeding tracks. There was general agreement, albeit with important differences, between the methods. The statistical classification did not seem to identify the differing scales of bedforms identified by the geologist, nor did it distinguish between sand waves and sand ribbons. On the other hand, the statistical classification used information at the scale of the acoustical wavelength (~3 mm) that may not have been considered the geologist. Further experimentation with the image patch size chosen for the statistical classification may improve the correlation between the methods. The Klein 5410 side scan sonar system is co-owned with the NOAA Office of Coast Survey.

Spatial and temporal patterns in eastern Bering Sea invertebrate assemblages Principal Investigators Cynthia Yeung and Robert A. McConnaughey (AFSC – RACE Division)

Invertebrate taxa exhibit highly specific geographical patterns reflecting their environmental requirements and ecological niches. These animals add important vertical complexity to the otherwise flat seabeds of the Bering Sea shelf and are also prey for commercially valuable species. In order to (1) characterize benthic habitats by invertebrate communities, and (2) detect temporal and spatial changes in community structure, invertebrate bycatch recorded during the annual RACE Division groundfish trawl surveys in the eastern Bering Sea (1982-2002) was examined. This study lays the groundwork for identifying the underlying biotic and environmental dependencies that define EFH for the benthic component of the eastern Bering Sea ecosystem. Spatio-temporal variability in the benthic invertebrate community structure is also a measure of natural and anthropogenic disturbance on the benthic environment, and clear, established community patterns could provide a basis for systematic study of fishing gear impact.

Of some 400 invertebrate taxa recorded over all the surveys, twenty-eight taxa were selected as the ‘core’ group for community analysis. They represent the dominant taxa in every survey either by frequency of occurrence (presence) or by biomass (kg/ha). Stations in each survey were grouped by the similarity of their assemblage of core taxa using hierarchical clustering. A persistent, interannual spatial pattern emerged of an “inshore” and an “offshore” group partitioned approximately along either side of the dynamic oceanographic “inner front” that runs mostly along the 50 m isobath (Fig. 5). Offshore-type stations are mostly of > 50 m in depth; inshore-type stations are characteristically of < 50 m in depth. Stations extending southwest along the coast of the Alaska Peninsula from Bristol Bay up to about the 100-m isobath near Unimak Pass and some around the Pribilof Islands also typically fall into the inshore category. The key inshore indicator taxon is the sea star, *Asterias amurensis*; the key offshore indicator taxa are Gastropoda, Paguridae, and the snow crab *Chionoecetes opilio*.

The inshore-offshore spatial structure of the epibenthic communities is robust across the 21-year time series. Variations in this typical structure are only evident in 1982-84 and 1998-99 (Fig. 5). Both periods saw a shoreward reduction in the domain of the inshore community (shoreward expansion of the domain of the offshore community). These anomalies coincided with significant climate events, namely the extreme El Niños in 1982-83 and 1997-98, and the Pacific Decadal Oscillation circa 1997-98. Multivariate ordination also indicates a trend of movement in the center of biomass of at least some of the core taxa towards the offshore (west). The dampening of these shifts in biomass distribution in the recent decade could signify the establishment of a stable and perhaps new spatial distribution of the taxa.

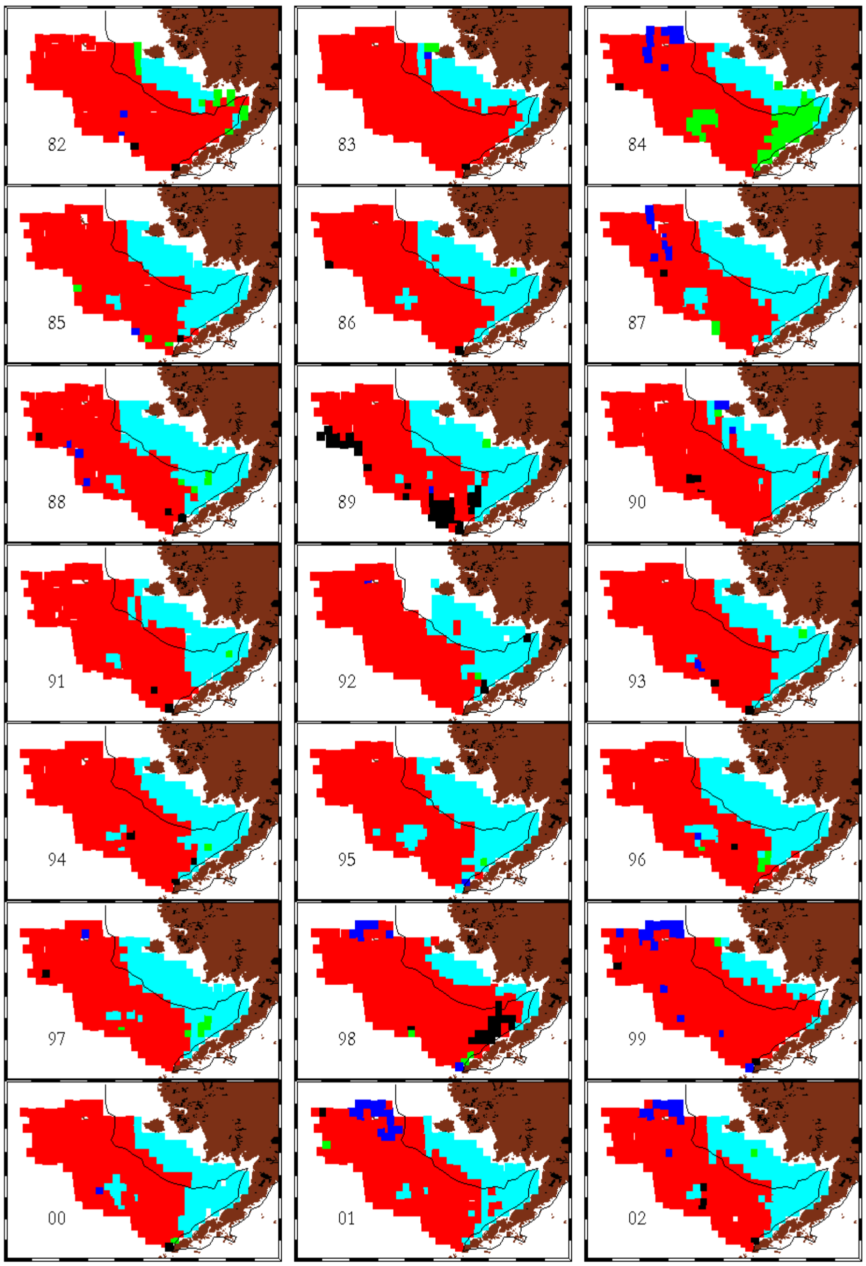

Figure 5. Survey stations clustered by the similarity of their core taxa assemblage. A maximum of 5 clusters are displayed. Stations are color-coded by cluster membership for visual interpretation. Colors are assigned to clusters to facilitate the spatial comparison of station groupings across surveys, not necessarily to imply the

same colored stations across surveys have the same underlying community structure. Solid black line delineates the 50 m isobath. The two largest clusters are respectively 'inshore' (cyan) and 'offshore' (red) of the 50 m isobath. Each panel has the 2-digit survey year.

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